WEARABLE SENSORS FOR CONTINUOUS PREGNANCY HEALTH AND ENVIRONMENTAL MONITORING: FROM A PATIENT AND PROVIDER PERSPECTIVE

by

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Abstract

Mobile health (mHealth)is an emerging field that uses mobile technology (i.e., mobile phones and various wireless technologies) to track and monitor a patient's medical health. Few studies have examined the perception of providers and patients with in the use of mHealth technology, particularly among pregnant women. This study evaluated the perception of both patients' and providers' attitudes towards mHealth and wearable technologies. Perception was gauged through a survey distributed November 15 through December 31, 2016 at Mountain Area Health Education Center (MAHEC) in western North Carolina in a rural, medically underserved area. Very few providers were currently using mHealth in their clinical practice. Results found that patients had a positive perception towards mHealth and welcomed its implementation into clinical practice while providers were more positive with regards to mHealth's potential in the future.

Keywords: mHealth, wearable technologies, pregnancy, maternal health, blood pressure

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Wearable sensors for continuous pregnancy health and environmental monitoring: From a patient and provider perspective

Mobile health (mHealth) technology is an emerging field that aims to provide more accessible forms of health care and health monitoring. Wearable technologies and mHealth allow providers to reach more people and serve more patients than they are currently able (Akter, D'Ambra, & Ray, 2010). Adopting mHealth technology requires understanding the perceptions of both the patients and providers who would use this technology. In this study, we conducted a survey to assess patient and provider perception towards mHealth in an effort to better understand how it can be adopted in the measurement of blood pressure (BP) in prenatal care. This study addressed limitations about the perception of mHealth and its application in prenatal care, specifically in the rural and medically underserved region of western North Carolina. mHealth has the potential to greatly improve clinical practice by using mobile technology (i.e., mobile phones and various wireless technologies) to track and monitor a patients' medical health.

Studies have shown that users have specific ideas in mind when thinking about utilizing wearable technology and mHealth. The users prefer technology that is easy to use, aesthetically appealing, long-lasting, reliable, and that transmits data in real time (Chan, Esteve, Fourniols, Escriba, & Campo, 2012; Derbyshire & Dancey, 2013; Pantelopoulos & Bourbakis, 2010; Sezgin, Özkan-Yildirim, & Yildirim, 2016). Users shy away from anything that would be expensive to them or require a great deal of effort from them (Chan et al., 2012; Pantelopoulos & Bourbakis, 2010; Sezgin et al. 2016). When considering mHealth, users from all demographics prefer technology that would not be much of a hindrance to them personally. Among pregnant women specifically, it has been found that mHealth

technology needs to be comfortable and movable, as well as safe for the mother and the baby (Nitulescu, Crisan-Vida, Stoicu-Tivadar, Bernard, 2015). Pregnant women tend to consider their baby first before themselves, so it is crucial to ensure that the technology be safe for the baby and that the mother would understand that.

Current mHealth technology allows providers to serve more patients and has the potential to improve the quality of life for patients (Chan et al., 2012). However, patients have qualms about the levels of privacy that the mHealth technology would give them, having to interact with the device, and having to be trained on how to use it (Chan et al., 2012). In addition, providers are nervous about the possible increased workload that it could bring them and that there is potentially little incentive for some to begin using this technology (Sezgin et al., 2016). Overall, patients are concerned about the potential privacy violations that mHealth may bring them, and providers are worried that it would bring them a far greater amount of work than the providers themselves are able to accomplish.

Various studies examined the implications that mHealth and/or wearable technology may have either on the patients and the providers (e.g., Chan et al., 2012; Derbyshire & Dancey, 2013; Nitulescu et al., 2015; Pantelopoulos & Bourbakis, 2010; Sezgin et al., 2016), identifying potential benefits and barriers that the adoption of mHealth into clinical practice may bring. In both studies, Pineros-Leano, Tabb, Sears, Meline, and Huang (2014) and Sinha and Varghese (2015) conducted in depth data collections to evaluate the perception that the providers have towards mHealth. Pineros-Leano and colleagues (2014) focused specifically on providers who work with pregnant or recently postpartum women.

In a small study in southern India, Sinha and Varghese (2015) conducted a survey assessing providers' perceptions towards mHealth applications. Providers determined that

mHealth applications for their practice provided the following benefits: assist in data collection from patients, improve communication with their patients, assist in clinical decision making, assist in their patients making payments, remind their patients about medications, and help monitor their patients in general. The providers were unsure or had no opinions about privacy, confidentiality, or whether the use of mHealth technology would reduce clinical visits from their patients (Sinha & Varghese 2015).

Pineros-Leano et al. (2014) conducted focus group interviews with twenty-five providers from a clinic in Illinois that serves low-income pregnant women. The researchers assessed the providers' thoughts about using mHealth technology to screen for postpartum depression in their patients. The providers identified the following as benefits to the technology: decreasing literacy and language barriers, decreasing redundancy and errors, and increasing privacy for the patients. In contrast, providers identified increased network issues and responsibility for technology as barriers to the technology (Pineros-Leano et al., 2014). The focus group concentrated specifically on the use of tablets in their office to perform screening surveys, though the benefits and barriers could be generalized to similar populations (i.e., low-income pregnant women). Used in a pregnant population, mHealth could be extremely beneficial to both providers and patients; it could allow for better communication and increase in privacy, contrary to the popular misconception that mHealth could provide privacy violations (related to storing data online or transferring data). Much of the literature regarding pregnancy and mHealth focuses on fetal monitoring; however, our goal is to identify needs and perceptions monitoring the pregnant woman's health, specifically her BP, as she progresses through pregnancy.

Certain populations are more at risk for adverse health outcomes related to their exposures, including pregnant women and a developing fetus (Rylander, Odland, & Sandanger, 2013). Preeclampsia, a condition characterized by maternal hypertension (i.e., increased BP) and proteinuria (i.e., increased protein in the urine), is the leading cause of maternal morbidity and mortality in the developing world(Roberts & Gammill, 2005). Preeclampsia impacts approximately 15% of preterm births and is the leading reason for pregnant women to be admitted into intensive care units (Roberts & Gammill, 2005). In developing countries where women are not monitored throughout pregnancy, preeclampsia causes 50,000 deaths annually (Roberts & Gammill, 2005). Monitoring BP clinically has been shown to greatly reduce maternal mortality. Prenatal care has shown to improve health outcomes for both the mother and baby. Lack of prenatal care has been linked to adverse birth outcomes including preterm delivery, low birth weight, and perinatal mortality (Abu-Ghanem, Sheiner, Sherf, Wiznitzer, Sergienko, & Shoham-Vardi, 2012).

Rural area residents face greater health disparities than people living in urban or suburban areas and are more difficult to reach with regards to their health (Eberhardt, Ingram, & Makuc, 2001; Sinha & Varghese, 2015). People living in rural areas are more likely than people living in urban or suburban areas to suffer from many conditions including infant mortality, diabetes, poorer overall health, and decreased health insurance rates (Eberhardt & Pamuk, 2004). A portion of this disparity can be attributed to demographic and socioeconomic factors (Eberhardt & Pamuk, 2004). Lack of health insurance has been linked to mortality (Wilper, Woolhander, Lasser, McCormick, Bor, & Himmelstein, 2009), as preventive health care services improve health and health outcomes (Sudano & Baker, 2011).

Many studies address the effectiveness of mHealth technology (e.g., Chan et al., 2012; Free et al., 2013; Signorini, Fanelli, & Magenes, 2013), but fail to evaluate perceptions towards mHealth. These perceptions must account for cultural, gender, and societal differences that affect mHealth adaptation in diverse areas. A gap in the literature has been identified in gauging the perception of patients and providers with regards to the use of mHealth technology, particularly among pregnant women. The objective of this study is to examine the acceptability and perception of mHealth and wearable technologies among patients and their providers to monitor their health, specifically BP, during pregnancy, in a rural, medically underserved area.

Study Area

Surveys were conducted through Mountain Area Health Education Center (MAHEC, year). MAHEC serves 16 counties in western North Carolina (WNC; i.e., Buncombe, Cherokee, Clay, Graham, Haywood, Henderson, Jackson, Macon, Madison, McDowell, Mitchell, Polk, Rutherford, Swain, Transylvania, and Yancey; MAHEC, 2016 and is primarily located in Asheville (see Figure 1). MAHEC serves patients of all ages, and provides primary, dental, obstetrics, and gynecological care. The facility serves 114,000 patients annually, and in 2016 provided $7.2 million of safety-net services to their low-income patients (MAHEC, year). Asheville is located in Buncombe County and has a population of about 250,000 (US Census Bureau, 2016). According to the US Census estimates (2016), approximately 51% of residents are female, and 16.5% of those females live below the poverty line. Because of the rural environment surrounding Asheville and relatively low median income level, people in WNC have a more difficult time accessing affordable and healthy foods; 16.3% of WNC is considered to be food-insecure (Western

North Carolina Vitality Index, 2012). The median household income for Buncombe County is $45,167, and 15.2% of the population lives below the poverty line (US Census 2016). Over 13% of the population does not have health insurance (US Census Bureau, 2016). WNC has one-third fewer physicians per 10,000 people than the rest of the state, which corresponds with higher death rates from cardiovascular disease, stroke, and cancers (Western North Carolina Vitality Index, 2012). Thirteen of the 16 counties that MAHEC serves in WNC are medically underserved communities by the standards of the Health Resources and Services Administration (MAHEC, 2016).

Method

Review of the Literature

A review of the literature was conducted to assess the current research on mHealth perception from the patient and provider perspectives. Articles were found using the search terms illustrated in Table 1. The search was conducted on Google Scholar and included articles from 2000-2017. From the search, eighteen articles were selected for review based on relevance to the current study; an article was considered relevant if it included the following criteria: patient or provider thoughts (perception) about mHealth, mHealth for pregnant women (either considered or currently in use), or identification of potential barriers or benefits that would come from using mHealth.

Survey Distribution and Data Collection

In the fall of 2016, patient and provider surveys were developed to examine the perception and level of receptivity to using wearable technology to monitor prenatal care. The Institutional Review Board of the researchers' institution approved this project. Surveys were electronically distributed using Qualtrics to family medicine and OBGYN (obstetrician-

gynecologist) providers, as well as pregnant patients attending the MAHEC clinic. Patients were given the option of either submitting an electronic survey or a paper copy and providers were emailed a link for the online version to the survey. Surveys were available in the English language only. The surveys contained questions on demographic information from the participants as well as questions designed to understand participants' perceptions towards mHealth. All of the questions were of multiple-choice format, and the majority allowed for the participants to provide additional comments for the specific question.

Statistical Analyses

Survey responses were manually entered and numerically coded using Excel and descriptively analyzed using IBM SPSS Statistics software (Version 24). Frequency tables were calculated to determine response rates and to compare responses between various groups. Chi-Square tests were calculated to determine relationships between variables, and significance was evaluated at alpha 0.05.

Results

We collected 102 patient responses and 28 provider responses. Patients ranged in age from 17 to 44 years of age. Patients came from a variety of racial and ethnic backgrounds and ranged in education levels from some high school through graduate or professional degrees. Most of the patients' first language was English, though some indicated Spanish or Moldavian. Providers ranged in age from 26 to 50 years of age and had been practicing medicine from a range of 0.5 to 25 years. The providers came from a variety of racial backgrounds, identified as family medicine practitioners or OBGYNs, and were MD faculty or medical residents.

Patient Survey

Table 2 describes the demographics of the pregnant patients who participated in the survey collection. The respondents were predominately white (86.4%) and English-speaking (96.1%). The patients ranged in age from 17 to 44 years old. Most of the patients had a high school diploma or General Educational Development (GED; 49.5%), with 43.7% having graduated college or a professional program. The majority of the women were either in a married or unmarried relationship (88.3%). Seven of the patients (6.8%) had a health condition in addition to their pregnancy (i.e., diabetes, neurological disorder, kidney disease, arthritis, clotting disorders, thyroid disorders, endometriosis).

When asked about devices that they currently use, patients most often reported cell phones (81.2%), smart phones (81.2%), and desktop or laptops (32.7%; "all the time" or "often"). Text messaging (90.2%), using the internet (78.7%), and making phone calls (74.8%) were found to be the most common uses of the patients' mobile phones ("all the time" or "often"). A total of 38.6% of the pregnant women (n = 39) downloaded a pregnancy application onto their smartphones (most commonly "Ovia Pregnancy Tracker and Baby Countdown" and "What to Expect") or began wearing devices to monitor their health when the patients became pregnant. The patients seemed unsure about carrying a GPS tracker while pregnant to monitor their exposure to the environment, with 28% of women (n = 28) in agreement and 32.0% (n = 32) neutral or undecided towards the statement.

Almost half of patients (49.0%) stated that they would be willing to wear a mobile sensor while pregnant to monitor their health, and 44.6% of patients agreed that they would be willing to wear a sensor in their maternity clothes to track their health status. When asked in which scenarios they would consider wearing sensors to monitor their health and

environment, patients preferred to monitor pregnancy health (76.5%), manage chronic diseases (71.1%), and monitor personal health and diet (67.4%). In the context of health monitoring, patients would prefer to track infant heart rate (80.4%), BP (73.0%), and their personal heart rate (69.8%) using mHealth during pregnancy. In the context of environmental monitoring, patients preferred to use mHealth to track chemical or pesticide exposure (68.1%), water quality (64.0%), and pollen (54.7%) during pregnancy.

Almost all of the patients (92.9%) responded that they would be comfortable sharing information from their personal monitoring devices with their doctor, while 86.6% of patients responded that they believed the type of information that can be obtained from mHealth or wearable technologies would improve their health and decrease their risk of disease, injury, or adverse pregnancy health events. A majority of patients (62.3%) would be more willing to wear sensors while they were pregnant if no one but themselves had access to the data. When asked how likely they would be to change their behavior during pregnancy in response to receiving personalized recommendations from their smart phone, 28.9% of patients (n = 28) responded “extremely likely,” and 46.4% (n = 45) responded “somewhat likely.”

Patients were asked how long during their pregnancy they would be willing to wear a GPS tracker. Only 29.7% of patients (n = 35) stated that they would wear the device throughout their entire pregnancy; nine patients stated that they would never be willing to wear the device. Out of the 118 total responses from 103 participants (patients were allowed to indicate as many of the answer choices that applied to them), 90 participants (76.3%) indicated that they would be willing to wear the device at some point during pregnancy.

The perception that patients have related to the privacy of mHealth and wearable technologies was assessed through the survey. Table 3 shows patient responses to survey

questions based on privacy. For all of the questions that were asked, a large percentage of women were undecided about their feelings towards the privacy aspect of the devices.

In analyzing the survey responses, data were calculated for those patients who responded that they would be willing to wear a mobile sensor during pregnancy and compared to responses overall. Figure 2 outlines the differences in responses. Overall, survey participants who responded positively to wearing a mobile sensor during pregnancy had less concerns related to privacy ($p < .05$) and responded with more acceptance to questions about implementing mHealth to track their health and environment during pregnancy compared to those who did not desire to wear a mobile sensor during pregnancy.

Provider Survey

The providers ranged in age from 26 to 50 years of age and had practiced medicine for a range of 0.5 to 25 years. None of the providers that responded to the survey were Hispanic or Latino. The majority (75.0%; $n = 21$) of respondents were male, with 25.0% ($n = 7$) female. Most of the providers were white (88.9%; $n = 24$); 7.4% ($n = 2$) were Asian, and 3.7% ($n = 1$) were Native Hawaiian or other Pacific Islander. There was a fairly even distribution between family medicine practitioners (53.6%) and OBGYNs (46.4%), as well as a fairly even distribution between medical residents (46.4%) and MD faculty (53.6%). Table 4 illustrates the demographics of providers.

A small proportion of providers currently utilized wearable technology in their practice (13.6%). Providers stated that they commonly used technology, such as smart phones, tablet computers, and cell phones, throughout the typical workday. During a typical workweek, providers stated that they most often accessed professional clinical reference tools (71.4%), emailed colleagues (64.3%), and checked drug recommendations for prescribing

and safety information on their mobile devices (60.7%). Least often, providers reported utilizing clinical notes, using e-Prescribe (prescribing medications electronically), or engaging with patients on their mobile devices. Seventy-six percent (n = 19) of providers were undecided about implementing mHealth or wearable technologies into their patient care. The majority of them (68.0%; n = 17) were also undecided about whether or not mHealth or wearable technologies are useful tools to monitor the health of their pregnant patients. In comparison, the majority of providers (56.0%) felt that in the future, wearable sensor technology will be used more often in the medical field to diagnose and remotely monitor patients; however, 32.0% were undecided about this.

In the context of health monitoring, providers preferred the use of mHealth to monitor blood glucose levels (88.0%), BP (80.0%), and chronic conditions such as asthma (56.0%) among their patients. Only 36.0% of providers desired to monitor infant heart rate. With regards to environmental monitoring, providers prefered to monitor chemical or pesticide exposure (32.0%), water quality (32.0%), and air quality (28.0%) using mHealth on their patients. When asked in which scenarios they would consider implementing wearable sensors in their clinical practice to monitor their patients' health and environment, providers favored personal health and diet monitoring (76.9%), chronic disease management (73.1%), and promoting behavior change (69.2%).

When asked at what point during pregnancy the providers would consider implementing the use of wearable sensor technology as part of their patient's clinical care, 47.8% (n = 11) of providers said that they would implement the technology "only at certain times," with 8.7% stating specific trimesters or durations. Only 17.4% (n = 4) of providers said they would implement the wearable technology throughout the entire pregnancy.

Interestingly, no providers selected “very good chance” when asked if they would implement wearable technologies during pregnancy.

Providers were given a list of outcomes and were asked which they saw as potential benefits to implementing wearable health technologies. Of the options, providers saw most potential in real-time monitoring of chronic disease (61.5%), improved patient communication and care coordination (57.7%), and remote monitoring and off-site diagnosis (53.8%). The providers were then given a list of outcomes and were asked which they saw as potential barriers or limitations to implementing wearable health technologies. Of the options, providers saw the largest barriers in adding another device or more data to hectic workflow (84.0%), generation of false alarms and heightened patient anxiety (80.8%), and lack of evidence in relation to clinical efficacy (73.1%).

These data were analyzed to determine statistical significance using a Chi-square test. Overall, the providers who currently use mHealth in their clinical practice expressed more acceptance of this technology to monitor the health and environment of their pregnant patients. The age of the provider was statistically significant ($p < .05$) in determining their interest in implementing mHealth or wearable technologies into their patient care; younger providers were more likely to be interested. Interesting, age was not statistically significant in whether or not the provider currently used mHealth in their clinical practice or if they felt that mHealth or wearable technologies would be useful tools to monitor the health of pregnant patients.

Discussion

Wearable technologies and mHealth have the potential to be beneficial in monitoring patients’ health, especially during critical life stages like pregnancy. Importantly, mHealth

can provide patients with the information that is crucial to track their health and observe any detrimental changes. When asked about wearing mobile sensors, one patient responded, “I think it would be beneficial information.” Overall, patients and providers responded positively towards the implementation of mHealth and wearable technologies, though patients seemed to have higher rates of approval towards the technology than did providers.

Some research has found that patients were nervous regarding the privacy or confidentiality that mHealth may inhibit (Chan et al., 2012), while other research has found that providers are undecided about the privacy and confidentiality effects that mHealth would have on their patients (Sinha & Varghese, 2015). Similar to Sinha & Varghese (2015), the current survey found that patients are undecided about their feelings of privacy regarding mHealth. The majority of patients were neutral or undecided towards privacy concerns regarding the types of data being recorded by the devices. Only 38.4% (“strongly agree” or “agree”) of providers believed that breaches of patient confidentiality were a potential barrier or limitation to implementing mHealth or wearable technologies. In depth interviews are needed to understand how patients and providers foresee the implications of mHealth on privacy and confidentiality for the patients.

Interestingly, patients and providers did not align in their preferences related to mHealth technology. Generally, patients were receptive to the idea of wearing mobile sensors to track their health; 49.0% said that they would be willing to wear a mobile sensor during pregnancy (26.5% said no), and 44.6% of patients said that they would be willing to wear a mobile sensor embedded in their maternity clothes to monitor their health (23.8% said no). Regarding what types of information patients and providers would like to track, opinions were similar but differed in levels of importance. Patients preferred to use mHealth to

monitor their pregnancy health, manage chronic diseases, and monitor personal health and diet, while providers preferred to use the technology to monitor their patients' personal health and diet, manage chronic diseases of their patients, and promote patient behavior changes. Patients preferred to monitor infant heart rate, BP, and personal heart rate, while providers preferred to monitor blood glucose levels, BP, and chronic conditions. This discrepancy may be attributed to there being more public knowledge about tangible health pieces (such as heart rate), while providers have more knowledge about underlying health issues caused by blood glucose levels, BP, and long-term chronic conditions.

Preeclampsia is responsible for the greatest percentage of maternal morbidity and mortality in the developing world, thus monitoring BP for hypertension is of greatest concern for providers (Roberts & Gammill, 2005). Blood glucose is indicative of gestational diabetes, a condition that leads to a high chance of cesarean delivery and dystocia (i.e., difficult birth; Casey, Lucas, McIntire, & Leveno, 1997). Providers typically observe fetal heart rate at each appointment that the woman attends, thus the providers are checking for abnormalities as they see fit. Conditions such as elevated BP or blood glucose cause much more concern for providers than do abnormalities in fetal heart beat or rate, leading to their preference to monitor those health statuses. Additionally, while 80.4% of patients responded that they would like to monitor infant heart rate, only 36.0% of providers showed preference to monitor infant heart rate.

In the context of environmental exposures, both patients and providers agreed that monitoring of water quality and chemical or pesticide exposure is of most importance. However, differences were noted for respiratory exposures, with patients requesting the monitoring of pollen and providers requesting the monitoring of air quality. Although the

preferences for environmental monitoring were similar between patients and providers, a higher percentage of patients than providers indicated that they wished to monitor those exposures, possibly illustrating that providers cared much more about the internal health of the patients than the environment by which the patients are surrounded. It is possible that the differences occur because patients and providers have different understandings of what aspects of health and the environment are crucial to overall health status, as well as differences in their health literacy (Lenert, Ziegler, Lee, Sommi, & Mahmoud, 2000; Williams, Davis, Parker, & Weiss, 2002). In depth interviews are needed to understand why preferences of the patients and providers differ so greatly and why each group prefers the specific health status indicator that they chose.

A plethora of studies have addressed the potential benefits, such as the ability to serve more patients, and barriers, such as breaches of confidentiality or time training to use the technology, of implementing mHealth and wearable technologies into clinical practice to monitor health (Chan et al., 2012; Derbyshire & Dancey, 2013; Pantelopoulos & Bourbakis, 2010; Pineros-Leano et al., 2014;Sezgin et al., 2016; Sinha & Varghese, 2015). The survey analysis in this study finds that providers at the MAHEC clinic foresee potential benefits as follows: real-time monitoring of chronic diseases, improved patient communication and care coordination, and remote monitoring and off-site diagnosis. The providers identified the following as potential barriers or limitations: adding another device and more data to a hectic workflow, generation of false alarms and heightened patient anxiety and lack of evidence in clinical efficacy. With regards to heightened patient anxiety, one provider stated “I feel we are setting ourselves up for a lot of worry that is unwarranted.” More research is needed to

understand how the potential benefits could improve clinical practice and also how to mitigate the potential barriers before problems arise.

The survey found that only 13.6% of providers are using mHealth technologies currently. When asked how the providers felt about implementing mHealth into their practice, an overwhelming majority of 76% remained undecided towards the question. This ambiguity may be attributed to the fear of increased workload from providers; it has been found that electronic records have greatly increased the amount of time that providers spend at work or on their documentation, thus it follows that providers might fear more electronics that could cause more work for them (Poissant, Pereira, Tamblyn, & Kawasumi, 2005). Despite the general ambiguity towards implementation of mHealth, 68.0% of providers strongly agreed or agreed that mHealth and wearable technologies would be used more in the future to diagnose and remotely monitor patients. This agreement shows that providers see the potential benefit that mHealth has in clinical practice but are not ready to take on the practice themselves. This may be due to the fact that the majority of providers that participated in this study were relatively new to their practice and may not be as established or comfortable in their practice as would be a provider who has been working for a longer time, but more in depth interviews would be needed with providers to determine the accuracy of that speculation. More in depth research is necessary to understand what providers need in order to implement mHealth (i.e., Khatun, Heywood, Ray, Bhuiya, & Liaw, 2016) and how this can be a more accessible topic for patients to understand and utilize.

Conclusion

This study found that mHealth could be effective in monitoring pregnant women's health and exposures during pregnancy. Both patients and providers reacted positively to the

idea of mHealth or wearable technology, though patients had a more positive reaction than providers. Patients had more positive reactions to implementing mHealth into clinical practice; whereas, providers were more undecided about current implementation but felt that in the future, mHealth would be a valuable tool. More in depth interviews are needed to further assess the reasons why patients and providers have their perceptions to mHealth and to examine how the potential benefits and barriers could affect clinical practice.

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Table 1

Search Terms Used in the Literature Review

	Pregnancy	Pregnancy complications
mHealth	7,640	3,330
Wearable sensors	3,300	1,410
Sensor monitoring	16,500	16,200
Personalized monitoring	16,100	16,600
Physiologic monitoring	18,500	18,800

Table 2

Demographic Characteristics of Pregnant Participants at the MAHEC Clinic in the Medically Underserved Region of Western North Carolina

Demographic	Patient responses (%)
Race	
White	89 (86.4)
Black	5 (4.9)
Asian	1 (1.0)
Mixed race	7 (6.8)
Other	1 (1.0)
Ethnicity	
Hispanic or Latino	6 (5.8)
Not Hispanic or Latino	97 (94.2)
Primary Language	
English	99 (96.1)
Spanish	1 (1.0)
Other	2 (1.9)
Declined to answer	1 (1.0)
Education	
Some high school	7 (6.8)
High school or GED	51 (49.5)
Associate's degree	13 (12.6)
College or professional degree	32 (31.1)
Current Relationship Status	
Married	58 (56.9)
Separated	1 (1.0)
Single	10 (9.8)
Unmarried relationship	32 (31.4)
Divorced	1 (1.0)
Widowed	0 (0.0)
Declined to answer	1 (1.0)

Note. MAHEC = Mountain Area Health Education Center; GED = General Educational Development.
n = 103.

Table 3

Perceptions of Privacy from Pregnant Participants at the MAHEC Clinic in the Medically Underserved Region of Western North Carolina

Statement	Response (%)
"Do you have any privacy concerns about the types of data (for example, GPS tracker, heart rate activity) being recorded by these devices?"	
Strongly agree	13 (13.1)
Agree	13 (13.1)
Neutral or undecided	53 (51.5)
Disagree	14 (14.1)
Strongly disagree	6 (6.1)
Declined to answer	7 (6.8)
"I have privacy concerns about data stored on my personal smartphone or a personal monitoring device."	
Yes	28 (27.7)
No	42 (41.6)
I don't know or undecided	30 (29.7)
Declined to answer	3 (2.9)
"I have privacy concerns about data stored on my smartphone or personal monitoring device being moved to a companion website or smartphone app."	
Yes	30 (30.0)
No	34 (34.0)
I don't know or undecided	35 (35.0)
Declined to answer	4 (4.0)
"I would wear a mobile sensor during pregnancy."	
Yes	50 (49.0)
No	27 (26.5)
I don't know or undecided	25 (24.5)
Declined to answer	1 (0.9)
"I would wear sensors embedded in my maternity clothes to allow me to monitor my heart rate, temperature changes, and other health indicators while pregnant."	
Yes	45 (44.6)
No	24 (23.8)
I don't know or undecided	32 (31.7)
Declined to answer	2 (1.9)

Note. MAHEC =Mountain Area Health Education Center .
$n = 103$.

Table 4

Demographic Characteristics of Providers at the MAHEC Clinic in the Medically Underserved Region of Western North Carolina

Demographic	OBGYN (%)	Family Medicine (%)
Age		
21-30	4 (33.2)	6 (40.0)
31-40	5 (41.5)	6 (40.0)
41-50	3 (24.9)	3 (20.0)
51+	0	0
Declined to answer	1 (8.3)	0
Gender		
Male	12 (92.3)	9 (60.0)
Female	1 (7.7)	6 (40.0)
Race		
White	11 (91.7)	13 (86.7)
Asian	1 (8.3)	1 (6.7)
Native Hawaiian or Pacific Islander	0	1 (6.7)
Declined to answer	1	0
Ethnicity		
Hispanic or Latino	0	0
Not Hispanic or Latino	12 (92.3)	15 (100.0)
Declined to answer	1 (7.7)	
Professional Title		
Resident	5 (38.5)	8 (53.3)
MD faculty	8 (61.5)	7 (46.7)
Years in Clinical Practice		
0-5	6 (46.2)	10 (66.7)
6-10	4 (30.8)	3 (20.0)
11-15	1 (7.7)	1 (6.7)
16-20	1 (7.7)	1 (6.7)
21-25	1 (7.7)	0
26+	0	0

Note. MAHEC = Mountain Area Health Education Center; MD = medical doctor; OBGYN = obstetrician-gynecologist.
OBGYN $n = 13$, Family Medicine $n = 15$.

Figure 1. Sixteen county region of western North Carolina served by the Mountain Area Health Education Center (MAHEC).

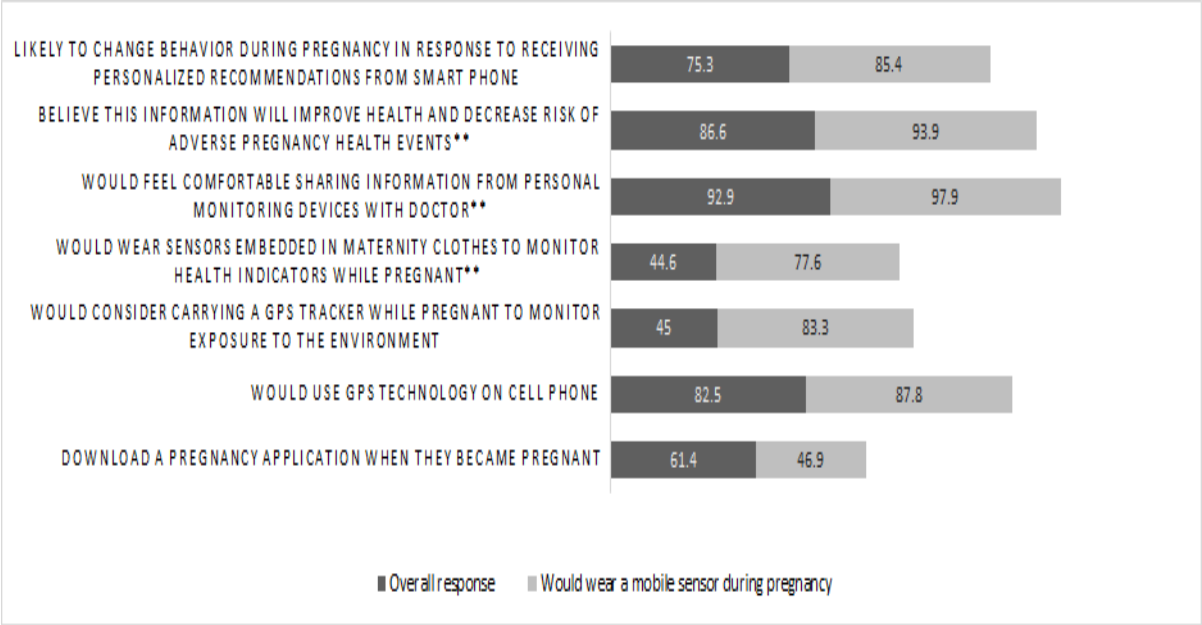

Figure 2. Difference in survey responses (in percentages) from pregnant patients overall compared to patients who responded "yes" to the statement "I would wear a mobile sensor during pregnancy" through the survey at MAHEC clinic in the medically underserved region of western North Carolina.
$^{**}p < .001$